Characterization of the Dynamic Response of Thick Composite Structures

ONR Grant No. N00014-96-1250
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Technical Performance Report #1
June 3, 1997

Summary

The objective for this research remains at contributing to the understanding of the fundamental mechanisms which determine the response of thick composite structures to time dependent loading.

The following specific objectives were originally proposed and, with some modification, continue to form the basis for the research plan:

1. Postulate the primary micromechanical attributes in the range of relatively small strain which are expected to directly affect frequencies, mode shapes, participation factors, and response magnitude. Such attributes will include material system, fiber density, ply thickness, cross ply geometry, strain rate sensitivity, accumulated damage, manufacturing imperfections, and others.
2. Choose a specific fixed-free beam geometry and considering both glass/thermoset and graphite/epoxy material systems, determine dependencies of fundamental modal quantities upon micromechanical attributes determined in 1. above. Develop predictive techniques using the ABAQUS™ FEM code.
3. Determine candidate damage mechanisms and resulting shifts in modal variables for subject material systems under time dependent loading.
4. Characterize the currently existing knowledge base concerning micromechanical effects on modes of vibration of composite structures. The work will build upon previous effort and is directed toward specifically categorizing behavior which would then contribute to optimum design of thick composites for high strain rate shock loading.
5. Document the results in media compatible with sponsor's Mechanics of Composites Program overall objectives and guidelines.

The research is proceeding according to the proposed plan as shown in Figure 1 below.

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Ref: ONR Grant N00014-96-1-1250

Encl: Technical Performance Report #1 (2 Copies)

Dear Sir/Madam:

Please find enclosed Technical Performance Report #1 for the University of Maine grant entitled "Characterization of the Dynamic Response of Thick Composite Structures".

Sincerely,

Richard H. Messier, Ph.D., P.E.
Associate Professor

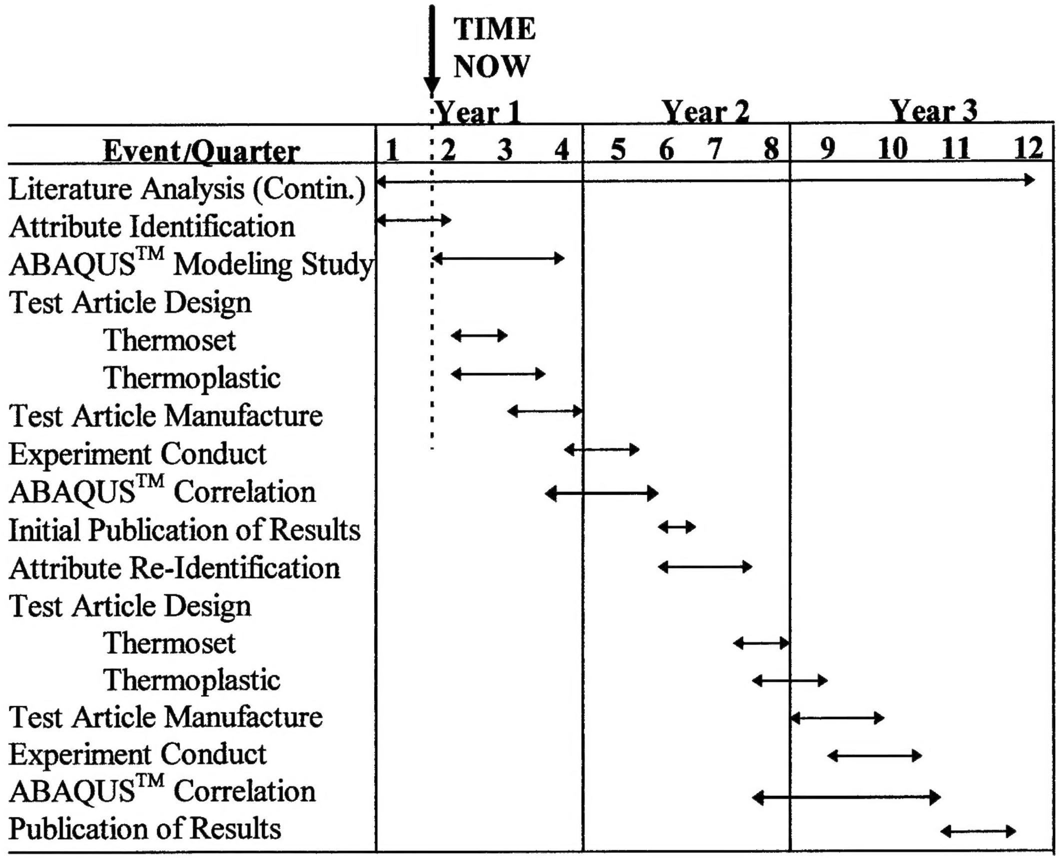

Figure 1

Significant Events and Overview of Technical Progress

1. The basic grant was awarded to the University of Maine (UMaine) effective September 1, 1996. A subcontract was issued by UMaine to Brunswick Technologies, Inc. (BTI) of Brunswick Maine, effective November 22, 1996. Purchase order agreements were reached by BTI with North End Composites, Inc. (NECI) of Rockland , Maine, and General Dynamics Electric Boat Division (EB, G. Leon) of Groton, Connecticut, shortly thereafter. In early December all participants were under contract and performing as proposed.

2. On November 1, 1996 a meeting was held at BTI for the purpose of reviewing the planned research. Attendees were Tim Johnson, BTI, George Leon, EB, Rick Messier, UMaine and Larry Thompson, UMaine.

   The primary purpose for the meeting was to discuss the original proposal to ensure that the proposed objectives, technical approach, and expected results were still relevant to the state of technology in thick composites.

   The original objectives centered on the need to understand the modal dynamics of thick composite structures, and the hypothesized relationship of the natural frequencies and mode shapes to the composite structural attributes. It was originally perceived that the ability to reliably predict the variation in natural frequencies and mode shapes through computational modeling will be important in design of structures using a "smeared properties" approach. The

point was made that the thrust here should be in using the understanding gained in the research to establish a reliable approach to "smearing" or averaging the properties of thick composites for design. In this way detailed FEM modeling could be used early in design to establish a composite structure with natural frequencies, mode shapes, and damping which are effective in withstanding the expected dynamic loads. The FEM model would then be useful in determining approaches to be used in averaging properties for later detail design of structures and components for the given loading. It was agreed that these objectives were relevant in terms of the directions being taken by both the commercial and military composites technology.

The technical approach originally proposed included computational modeling and experimental verification. The FEM code ABAQUS™ is intended for use in computational modeling. A fixed-free beam configuration is intended for use in experimental study of the dynamic response of thick composite structures on a vibration table. The proposed approach is to use ABAQUS to predict natural frequencies and mode shapes based upon very detailed structural modeling, and to attempt experimental correlation using the vibration table. It was agreed that this approach remains generally correct, but two related issues were discussed at length in the meeting.

First, the potential material system(s) to be used for study was discussed. Originally, it was believed at the time that graphite/epoxy systems were important and that our work should include both thermoset and thermoplastic variants. We also proposed glass/thermoset resin systems for investigation. The point was made that the emphasis is changing somewhat in both military and commercial thick composite technology to more affordable material systems. Glass/thermoset SCRIMP™ or VARTM™ processes with innovative hybrid fiber and coring approaches, for example. A lengthy discussion also took place in consideration of the effect of environmental conditions (particularly temperature) on the performance of thick composite structures. It is recognized that, with limited resources, we must be certain to focus our efforts sharply in order to produce meaningful results. After much discussion, we agreed on a thick composite material systems approach that includes a so-called "low end", "mid range", and "high end" system. It was also agreed to focus initially on room temperature. By narrowing the infinity of possible material systems we simultaneously provide a structure to the proposed work that was not clear in the original proposal. Candidate thick composite material systems are:

low end	glass/thermoset resin SCRIMP with uni-directional fiber orientation
mid range	glass/thermoset resin SCRIMP with multi-directional fiber orientation
high end	graphite/epoxy thermoset (autoclave or in-situ) <u>or</u> glass/carbon/epoxy hybrid SCRIMP (cored)

The determination of the high end material system requires additional work and discussion. The intention in material system choice remains to study thick composite material systems which are relevant to current technology. The point was made that we must choose material systems for which there is currently available data on feasibility, performance, and properties. While the material system per se is not critical to the results of the work, it was agreed that we should choose material systems for study which are important in terms of the industry direction.

3. Experimental procedures have been developed for determination of composite material modulus, natural frequencies of free vibration, mode shapes, and other material and structural attributes. The procedures have been validated using an MTS servo-hydraulic tensile testing machine and the Mechanical Engineering Department's vibration testing (shaker) table and associated data gathering electronics. A variety of thick SCRIMP material samples with various fiber orientations have been used in this effort. Figure 2 below shows a typical thick composite material sample in a three point bending apparatus. Figure 3 shows a fixture in use for imposing fixed free boundary conditions on vibration test articles. This fixture is mounted directly on the shaker table and frequency response determined using accelerometers placed on the test article.

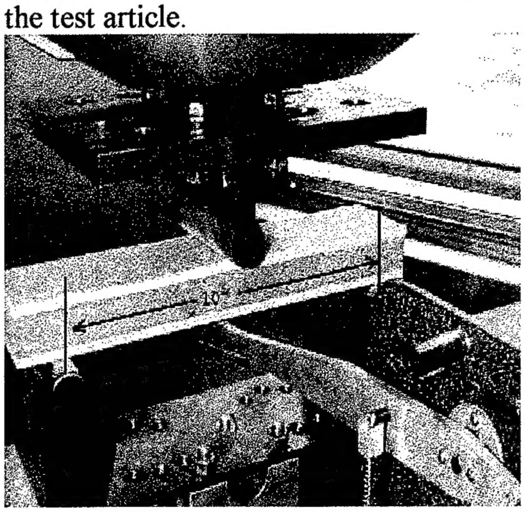

Figure 2

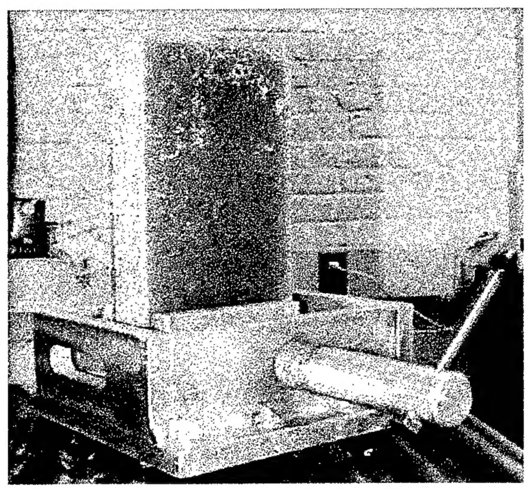

Figure 3

4. A proposal has been developed and submitted for internal funding to be used for the purchase of a much larger shaker table and associated equipment. The shaker table currently in use is limited to a total capacity of 20 lb, including fixture and test article. While the weight limit has not has not adversely affected the work to this point, it is believed that the larger capacity of the new equipment would benefit the research through potential use of larger test articles and fixtures in the future. The expectation is that the proposal will be favorably received and the funding will be provided.
5. Several Finite Element Method (FEM) studies have been completed using the ABAQUS™ code. Both lamina and smeared properties approaches have been utilized. Frequencies and mode shapes have been extracted and compared with shaker table results on multiaxial fiber test articles received from BTI. Agreement has been reasonable.

6. Initial test articles to be used in the research have been designed. These designs include both uni-directional fiber orientations with varying glass/matrix ratios by lamina, and 0/90 multi-directional fiber orientations. These designs have been forwarded to BTI and NECI for fabrication. Delivery is expected during the month of June.
7. During April 8-10 the research team attended the Maine Science and Technology Foundation Composite Materials Technology Conference in Portland, Maine. Composite structure designers and fabricators from many sections of the U.S. and Canada were in attendance. Numerous presentations were offered, focusing primarily on manufacturing techniques.

Meetings Held

On November 1, 1996 a research team meeting was held at BTI. The details of discussions held at this meeting are provided under the Significant Events section above.

UMaine team meetings are held weekly to review progress and discuss plans and accomplishments.

Deliverables

1. Technical Performance Report dated June 3, 1997.

There were no additional deliverables planned for this period.

Concerns, Problems, Issues

None to report.

Plans for Next Reporting Period

Effort for the next period will be focused on completing fabrication of initial test articles and conduct of shaker table experiments to determine natural frequencies and modes of free vibration.